NACA RM L56K02

NACA

RESEARCH MEMORANDUM

INVESTIGATION OF THE INFLUENCE OF THE BOUNDARIES OF A HIGH-SPEED FREE WATER JET ON THE PLANING LIFT OF A FLAT PLATE

By John R. McGehee

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

March 20, 1957
Declassified June 24, 1958

NACA RM L56K02

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

INVESTIGATION OF THE INFLUENCE OF THE BOUNDARIES OF A HIGH-SPEED FREE WATER JET ON THE PLANING LIFT OF A FLAT PLATE

By John R. McGehee

SUMMARY

An investigation has been conducted to determine the influence of the boundaries of a high-speed free water jet on the planing lift of a flat plate operating on the surface of the jet. The flat plate was tested in jets having a constant width and varying depths, a constant depth and varying widths, and also in Langley tank no. 2, which has relatively great depth and great width as compared with the size of the flat plate used in this investigation.

No appreciable influence of speed on the planing lift coefficient for speeds from 50 to 200 feet per second was observed. The parameters determining the jet size required for a given test condition have not been defined by these brief tests. Apparently, a jet having a width of three model beams and a depth of two model beams is sufficient to give the equivalent of tank planing data obtained from the same size model for the range of parameters covered in this investigation.

INTRODUCTION

The use of a free water jet as a means of obtaining high-speed planing data was investigated, and the results are reported in references 1 and 2. These investigations showed that the planing lift obtained, with the size of jet used for the investigations of references 1 and 2, was less than that obtained in a conventional towing tank. An empirical correction was used in these references to reconcile the differences observed.

In an effort to determine the extent to which moderate-size jets could be used in obtaining planing-lift data that would require little or no correction in order to compare with similar data obtained in towing

tanks, a brief investigation has been made of the influence of jet size and proportion on the planing lift of a flat plate. The jet data, compared with data obtained on the same size model in Langley tank no. 2 and with the planing theory of reference 3, are presented in this paper.

SYMBOLS

B	width of nozzle exit, in.
b	beam of models, 0.72 in.
C_L	hydrodynamic lift coefficient, $\frac{L}{\frac{\rho}{2}SV^2}$
C_{L_j}	hydrodynamic lift coefficient obtained from jet data, $\frac{L_j}{\frac{\rho}{2}SV^2}$
C_{L_t}	hydrodynamic lift coefficient obtained from tank data, $\frac{L_t}{\frac{\rho}{2}SV^2}$
d	draft from trailing edge of model (measured vertically from upper edge of nozzle exit), in.
H	height of nozzle exit, in.
L	hydrodynamic planing lift, lb
L_j	lift obtained from tests conducted in jets, lb
L_t	lift obtained from tests conducted in tank, lb
l	wetted length of models, in.
P	gage static pressure in jet reservoir at level of the nozzle, lb/sq in.
S	wetted area of models, $\frac{lb}{144}$, sq ft
V	speed (speed equivalent to static pressure in jet reservoir at level of nozzle for jet tests), $\sqrt{\frac{144P}{\rho/2}}$, fps

τ trim (angle between bottom of model and horizontal jet axis), deg

ρ mass density of water, 1.94 slugs/cu ft

DESCRIPTION OF MODELS

The models were made of transparent plastic so that the wetted lengths could be photographed through the models. In an effort to keep model deflections to a minimum, a separate model was provided for each wetted length tested in the jet. This permitted the center of pressure to be located near the model support for each wetted length, while leaving a clear view for photographing the wetted length. Only one model, suitable for all wetted lengths, was used in the towing-tank tests, since the lower test speeds produced much smaller forces and therefore smaller deflections that could be neglected. The models were constructed as shown in figure 1. Holes were drilled through the models, parallel to and 1/16 of an inch above the bottom, at intervals of 0.200 inch to provide transverse lines for reading wetted lengths.

APPARATUS AND PROCEDURE

A description of the jet apparatus and its operation is presented in reference 1. By proper orientation of the nozzles used in this investigation, it was possible to make tests on jets of seven different proportions. For a jet width of 1.50 inches, jet depths of 0.75, 1.50, 2.25, and 3.00 inches were obtained; and for a jet depth of 1.50 inches, jet widths of 0.75, 1.50, 2.25, and 3.00 inches were obtained.

The models were tested in each of the jets and in Langley tank no. 2 (6 feet deep and 18 feet wide) at trim angles of 4°, 12°, and 20° and at length-beam ratios approximating values of 1, 2, and 4. The test speeds were from 160 to 200 feet per second in the jets and from 50 to 80 feet per second in the tank.

The tests in the jets were made by setting the draft of the model trailing edge, determined from the scheduled wetted lengths l and angles of trim τ, vertically from the upper edge of the nozzle exit. The actual wetted lengths were determined from photographs of the model taken with a 35-millimeter motion-picture camera located above the model and operating at approximately 12 frames per second. Typical photographs of the model, for determining wetted lengths, are shown in figure 2 for a set length-beam ratio of 2, a speed of approximately 200 feet per second, and trims of 4°, 12°, and 20°.

Electrical strain-gage balances, with ranges of lift forces from 0 to 50 pounds, 0 to 200 pounds, and 0 to 300 pounds, were used to measure the lift obtained in the jets. The measurements were recorded by an oscillograph and the estimated accuracy of the measuring and recording system is as follows:

Trim, deg	±0.1
Pressure, lb/sq in.	±1.0
Wetted length, in.	±0.1
Lift, lb	±1 percent of full-scale values of balances

The photographic record of the wetted lengths and the oscillogram of the lift and the pressure P, from which the jet speed was determined, were correlated by use of a signal generated at the camera that produced a pip on the oscillogram as each photograph was taken.

The tank tests were made using the Langley tank no. 2 towing carriage and the forces were measured on an electrical strain-gage balance, which had a range of lift forces from 0 to 50 pounds. The tests were made by accelerating the towing carriage to the desired speed and then lowering the model into the water to the desired nominal wetted length. Underwater photographs were taken to determine the actual wetted lengths. The estimated accuracy of the measurements taken in the tank is as follows:

Trim, deg	±0.1
Speed, fps	±0.5
Wetted length, in.	±0.1
Lift, lb	±0.5

There was some difficulty in obtaining adequate accuracy in both the jet and the tank. In the jet difficulty was experienced in obtaining the wetted length accurately because of the mixing zone on top of the jet. This caused the greatest proportional error at the low drafts run in the 4° trim tests. The accuracy of the data obtained from the tests conducted in the tank was limited because the model was considerably smaller than those for which the tank testing apparatus was designed and, therefore, was subject to errors proportionally larger than normal.

Because of deflections in the balances and variations between the set wetted lengths and the photographed wetted lengths, the data were not obtained at exactly repeatable values of trim or wetted length. In order to present the data with trim and wetted length as parameters, it was necessary to first cross-plot the data and apply changes in trim which were determined during calibration of the balances. As a result, the points appearing in the data figures were taken from cross fairings.

RESULTS AND DISCUSSION

The results of the investigation are presented as plots of lift coefficient against speed, at trim angles of 4°, 12°, and 20°, with wetted-length—beam ratio as the parameter. The data obtained in the jets having constant width and variable depths and those having constant depth and variable widths are presented in figures 3 and 4, respectively. The data obtained in the tank are presented in figure 5. In each case the lift coefficients were substantially constant over the range of speeds investigated.

The effect of jet depth is illustrated in figure 6 where lift coefficient is plotted against jet depth in model beams (H/b). In the shallowest jet the lift is appreciably less than that obtained in the deeper jets. For the three deepest jets, however, there is not much consistent variation of lift with the depth of the jet. The variations that do occur are presumed to be due to experimental accuracy. Evidentally, for the test conditions illustrated, a jet depth of a little more than two model beams is adequate and further increase in jet depth does not change the lift significantly.

The effect of jet width is shown in figure 7 where lift coefficient is plotted against jet width in model beams (B/b). This figure indicates a consistent increase in lift with increasing jet width up to a jet width of about three model beams. There is not much difference in the lift coefficients computed from data measured in the two widest jets; and, apparently, further increases in jet width have little effect on the lift coefficients.

It will be noted that the tests showing the effect of jet depth (fig. 6) were made at a jet width of 2.08 model beams. As indicated in figure 7, this width is in the region where width has an effect on lift coefficient; and, consequently, all the lift data in figure 6 would be expected to lie below lift values obtained in a stream of infinite size. However, the jet depth used in the investigation of width (2.08 model beams) is seen in figure 6 to be large enough to give substantially the same values as obtained at the greater depths. Hence, the two widest jets appear to be large enough so that increases in neither width nor depth would change the lift coefficients significantly. The lift-coefficient values in this region should then be comparable to those that would be obtained in a conventional towing tank.

Values of lift coefficient from the faired curves of figure 7, representing the widest jets, are compared in figure 8 with tank data for the same size model; they are also compared with values calculated by the theory of reference 3 by using the sharp-chine value of cross-flow drag coefficient $\left(C_{D_c} = 4/3\right)$. There is fairly good agreement

between the tank and jet data over most of the range shown in figure 8. The notable discrepancies are attributed largely to the difficulties in obtaining accurate data mentioned in the procedure. The discrepancy between tank and jet data at the highest trim and length-beam ratio might be due to the extreme draft condition that it represents in the jet. In any case, the evidence is that, for at least most of the range shown in figure 8, the jet is large enough to give substantially the same results as can be obtained in a conventional towing tank.

As might be expected from consideration of the edge effects demonstrated in reference 3, the data for the small plastic model fall below the planing lift predicted by the sharp-chine planing theory. This theory has been found to be valid for planing surfaces with very sharp chines such as can be obtained with carefully constructed metal models. Presumably, there was sufficient rounding of the edges of the plastic models used in the present test to account for differences between measured and theoretical lift. Methods of evaluating these rounded chine effects from the model geometry have not yet been developed. Therefore, close comparisons with other model planing data would require evaluation of these edge effects for both models.

CONCLUDING REMARKS

No appreciable influence of speed on the planing lift coefficient for speeds from 50 to 200 feet per second was observed. The parameters determining the jet size required for a given test condition have not been defined by these brief tests. The jet depth required is presumed to depend on a number of factors which include the maximum draft to be tested. Apparently, a jet having a width of three model beams and a depth of two model beams is sufficient to give the equivalent of tank planing data obtained from the same size model for the range of parameters covered in this investigation.

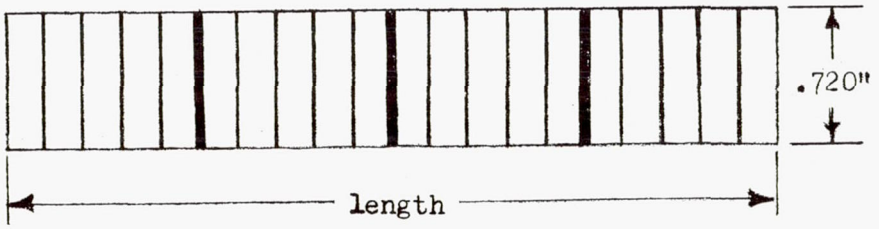
Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 16, 1956.

REFERENCES

1. Weinflash, Bernard, and McGehee, John R.: An Investigation of a Method for Obtaining Hydrodynamic Data at Very High Speeds With a Free Water Jet. NACA RM L54D23, 1954.

2. McGehee, John R., Weinflash, Bernard, and Pelz, Charles A.: The Hydrodynamic Planing Lift of Four Surfaces As Measured in a 200-FPS Free Jet. NACA RM L54F01, 1954.

3. Shuford, Charles L., Jr.: A Theoretical and Experimental Study of Planing Surfaces Including Effects of Cross Section and Plan Form. NACA TN 3939, 1957.



Models constructed of transparent plastic

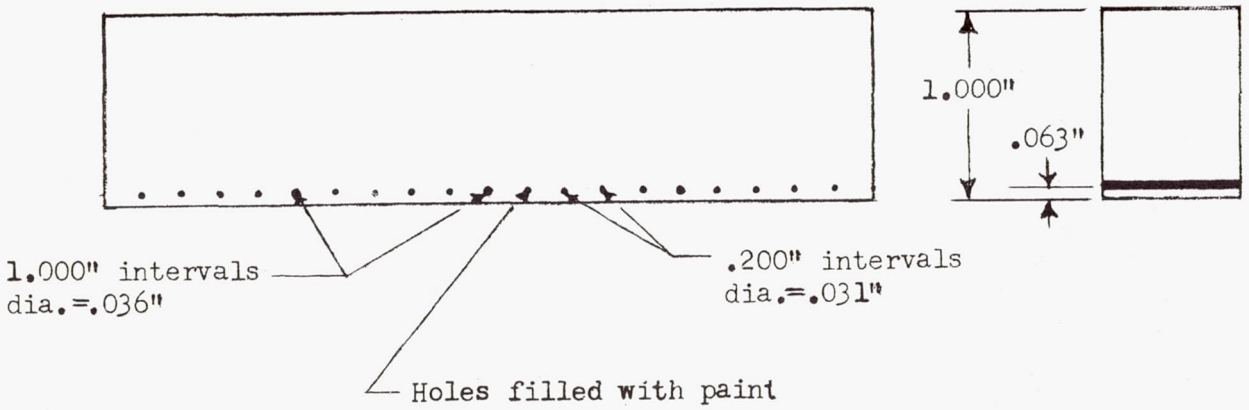
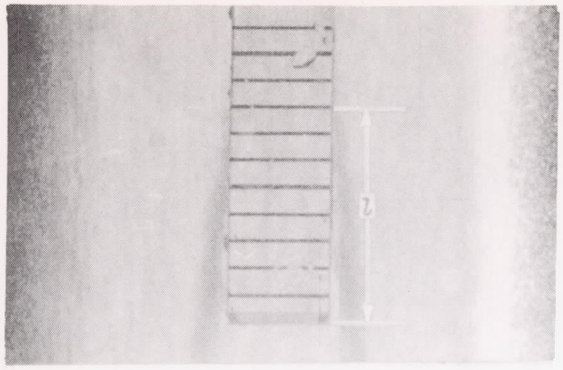
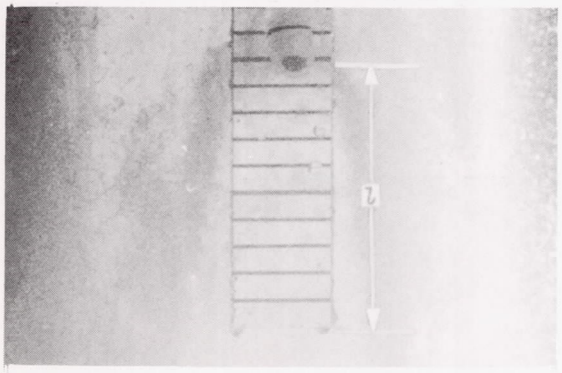


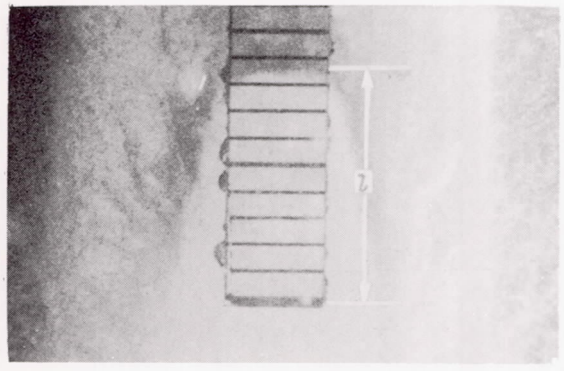
Figure 1.- Details of models.



(a) Trim, 4°.

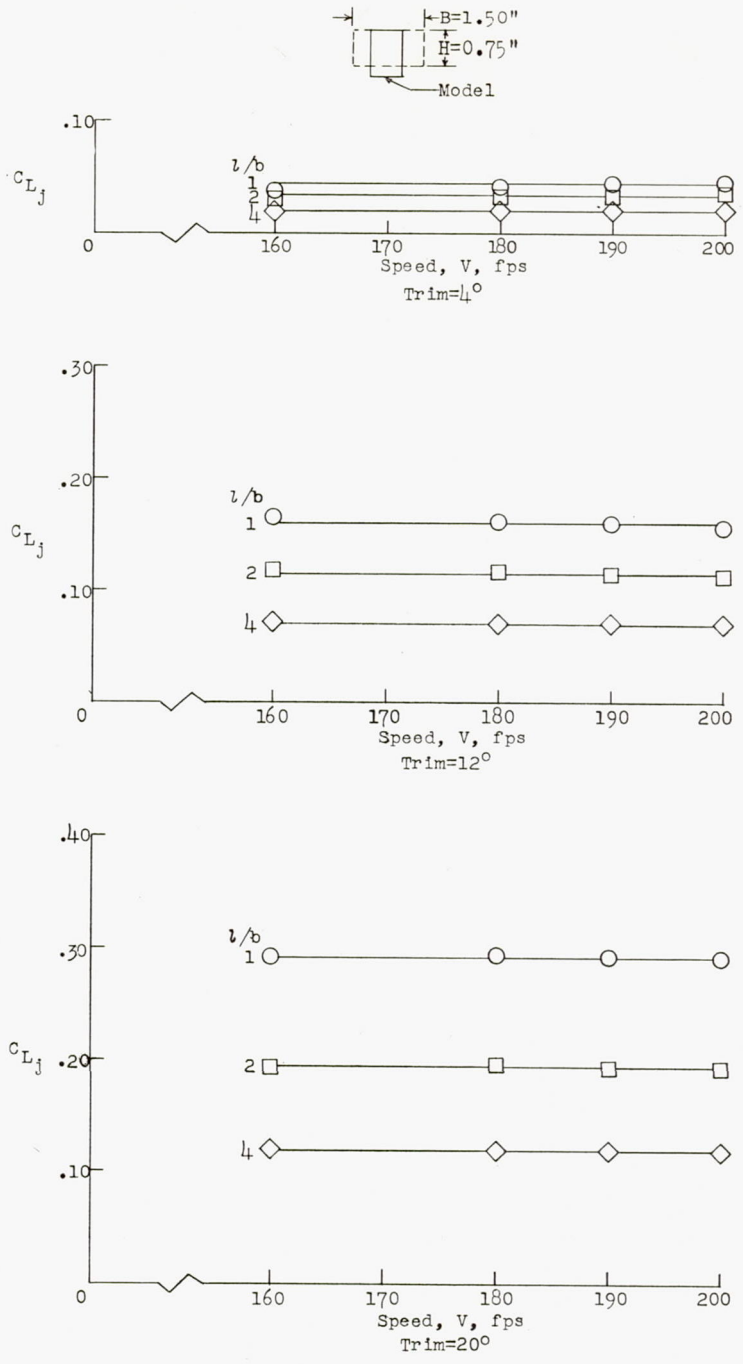


(b) Trim, 12°.



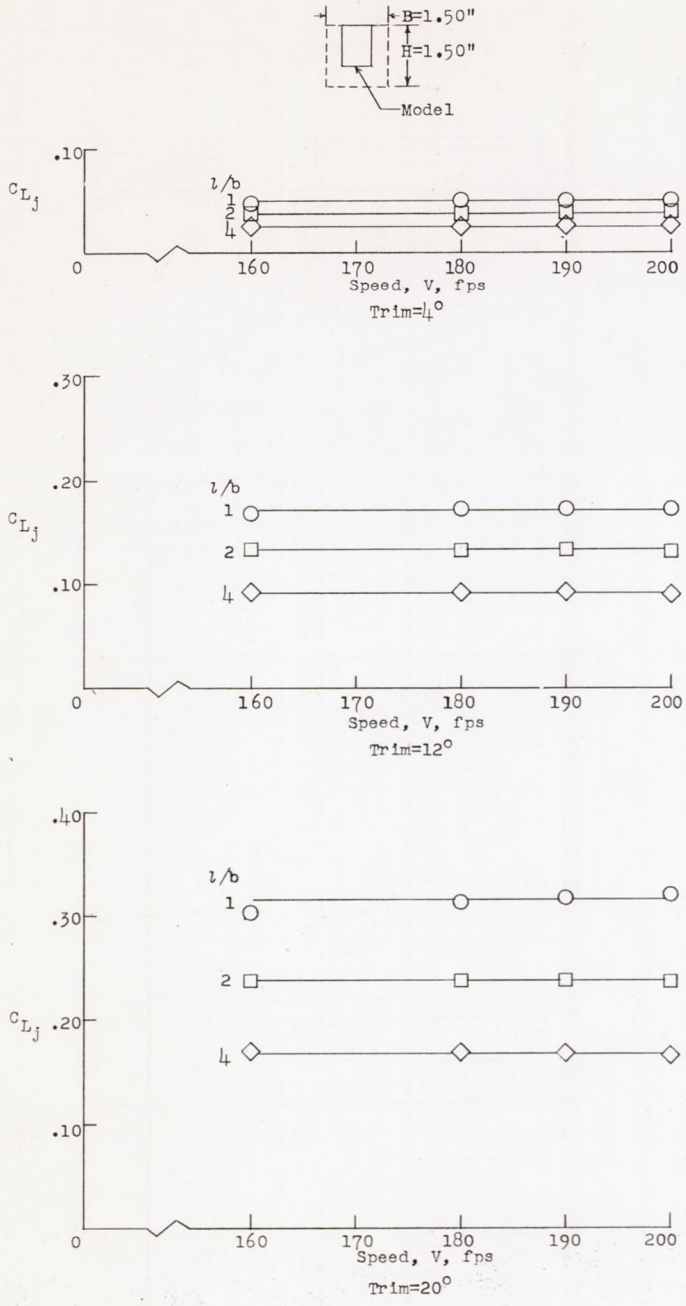
(c) Trim, 20°. L-95875

Figure 2.- Typical photographs of model for determining wetted areas. $l/b = 2$; $V \approx 200$ feet per second.



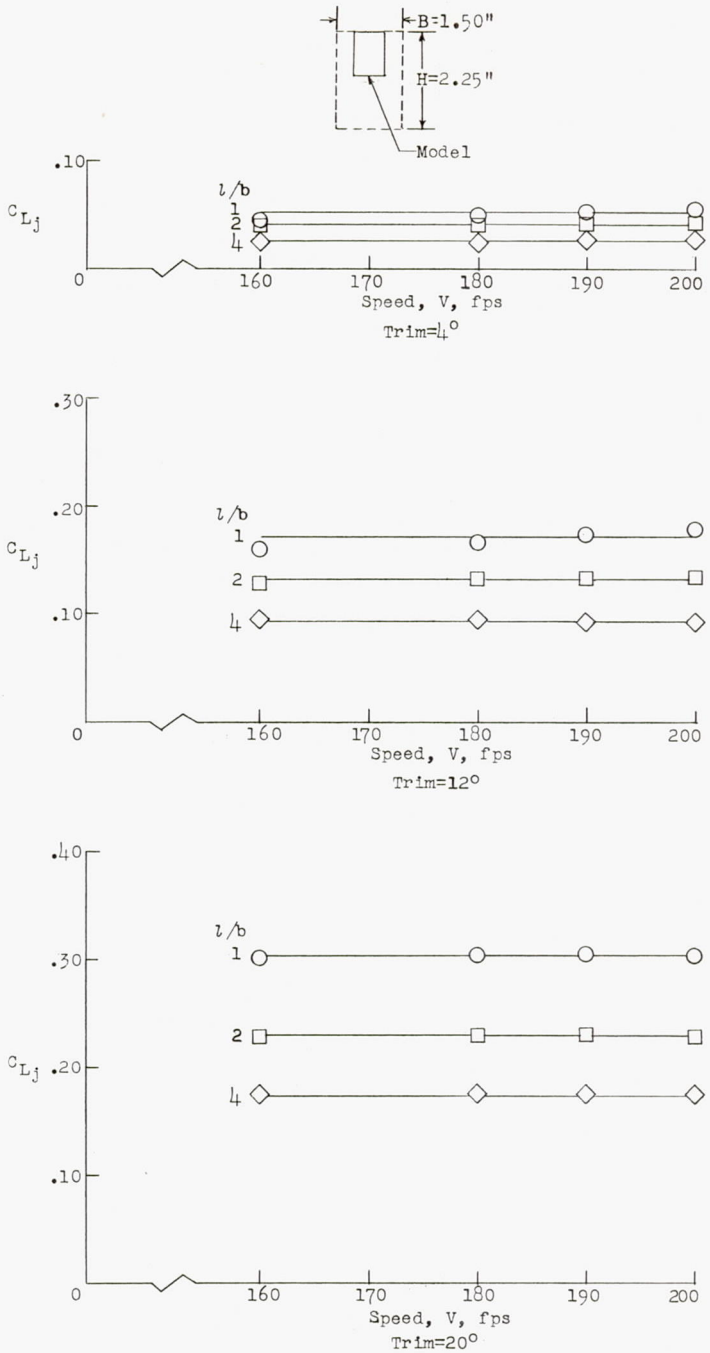
(a) H = 0.75 inch.

Figure 3.- Lift coefficients obtained in jets. Jet width, 1.50 inches.



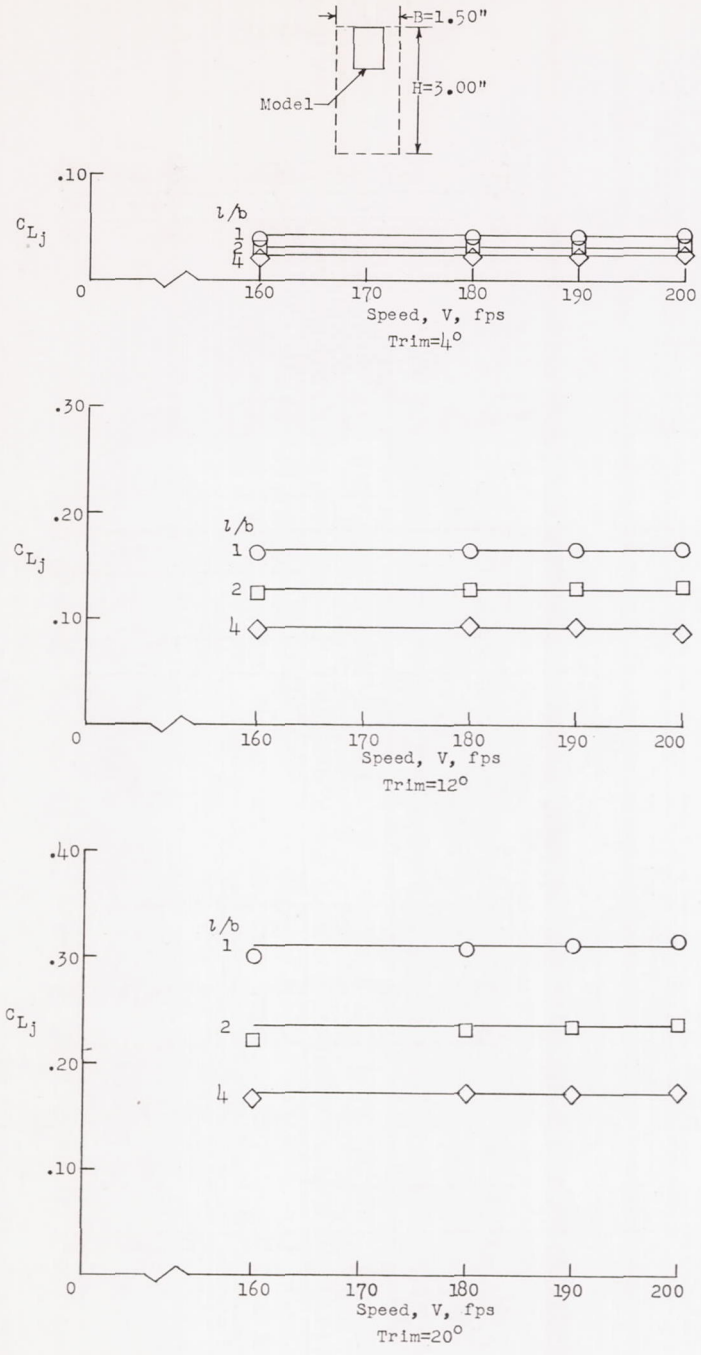
(b) H = 1.50 inches.

Figure 3.- Continued.



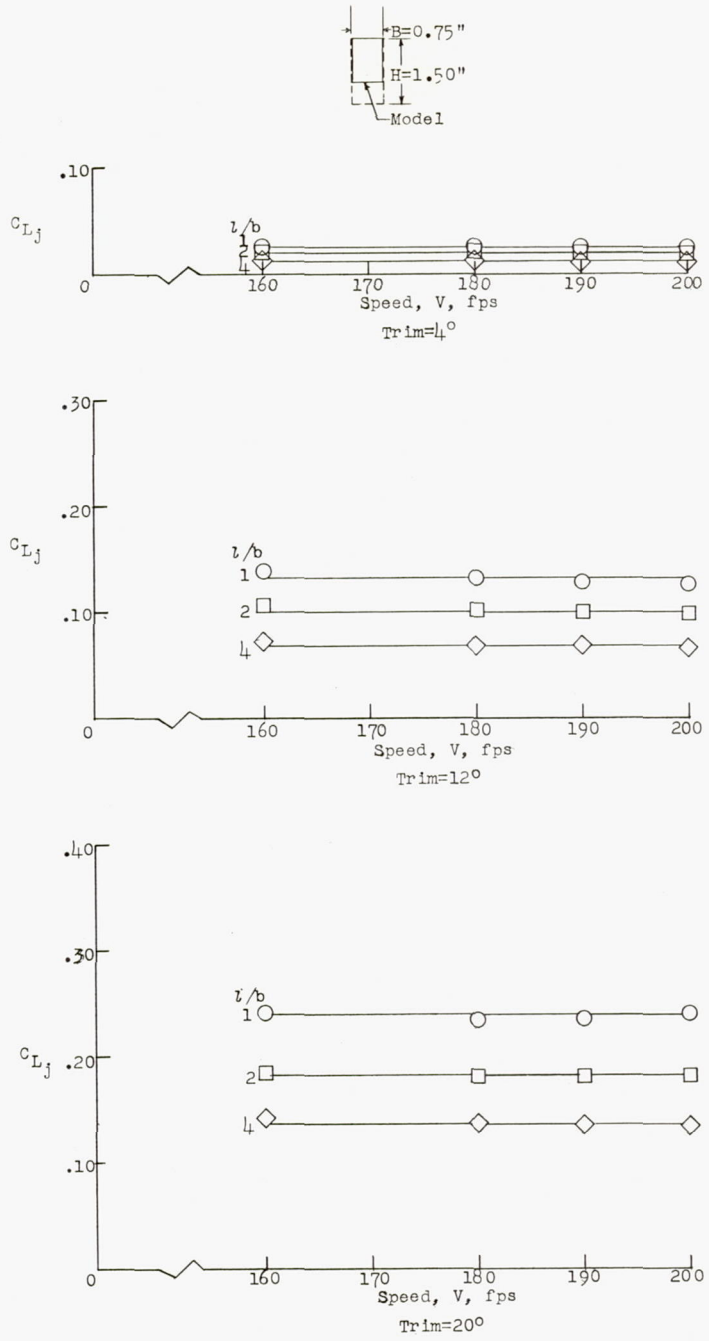
(c) H = 2.25 inches.

Figure 3.- Continued.



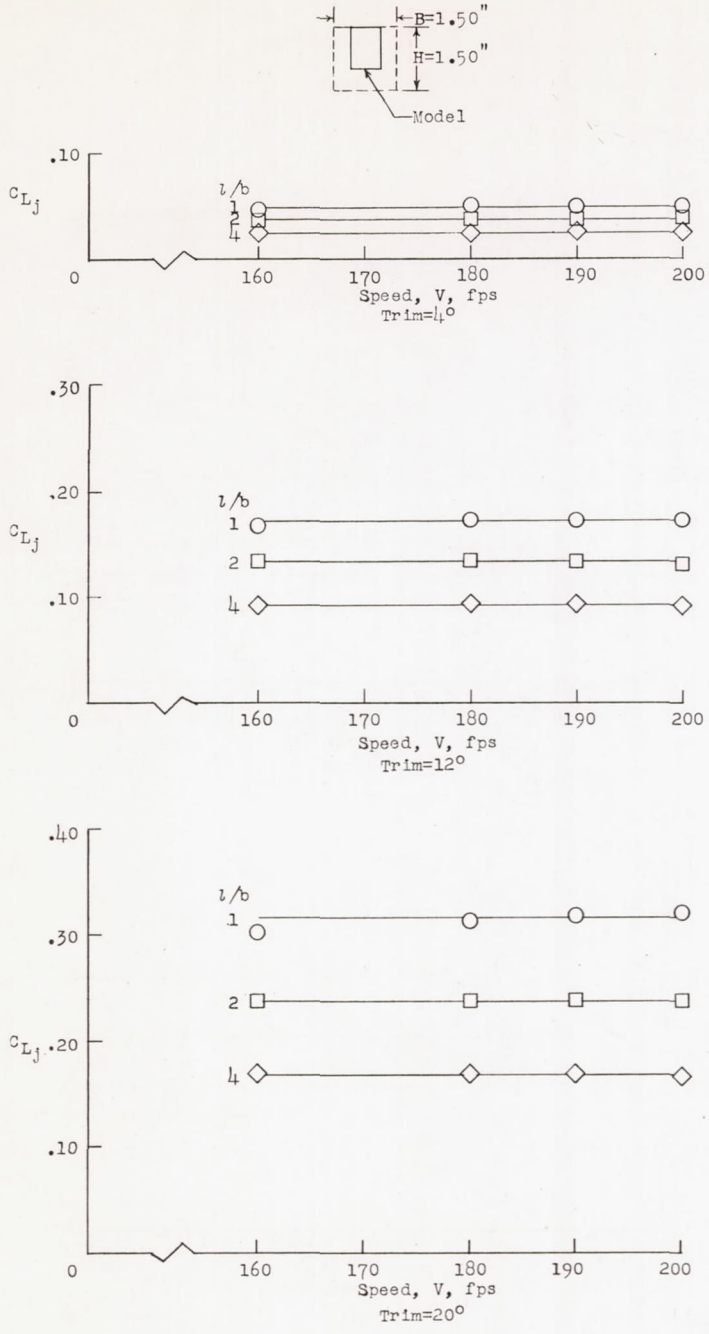
(d) H = 3.00 inches.

Figure 3.- Concluded.



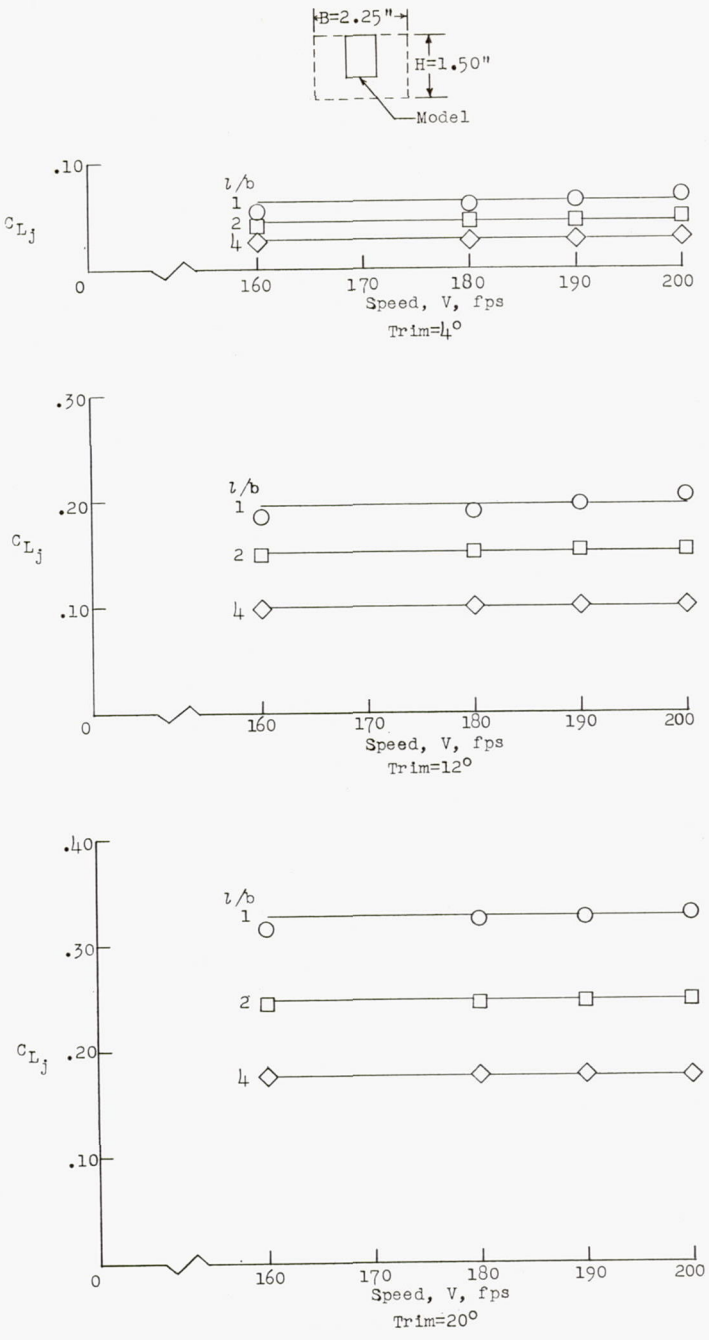
(a) B = 0.75 inch.

Figure 4.- Lift coefficients obtained in jets. Jet depth, 1.50 inches.



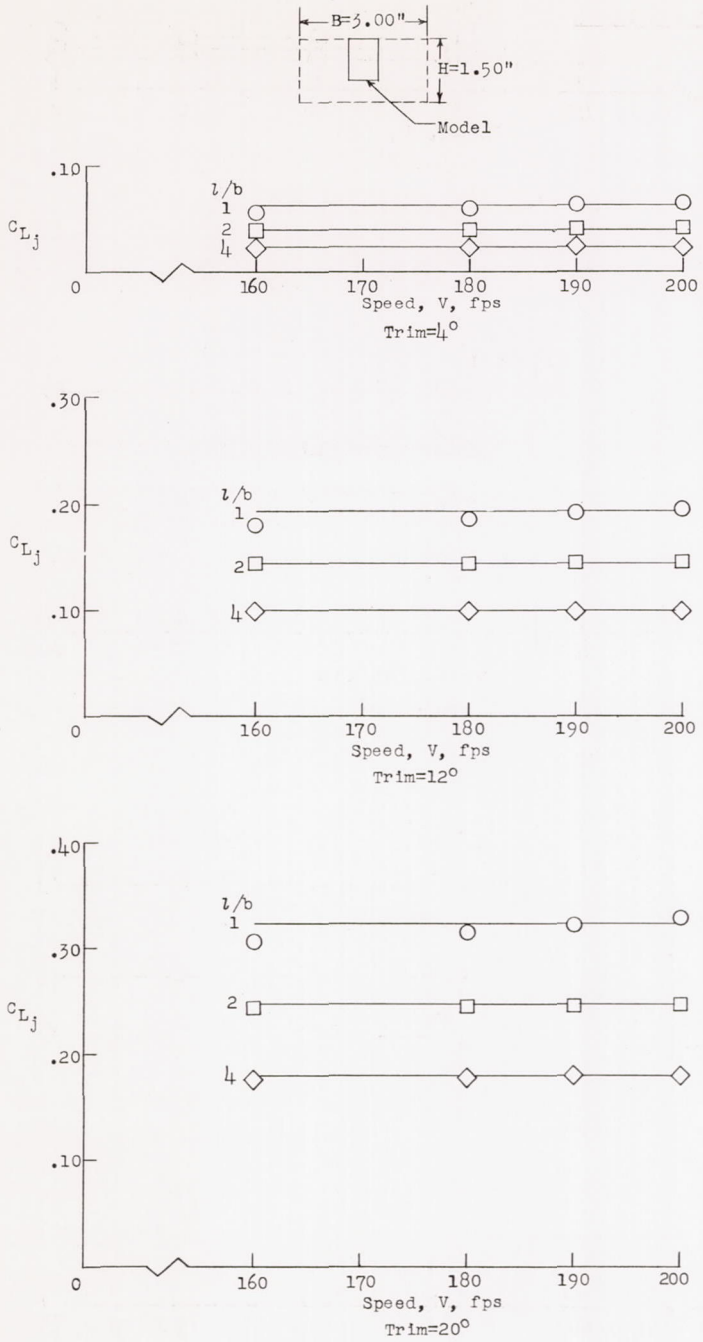
(b) B = 1.50 inches.

Figure 4.- Continued.



(c) B = 2.25 inches.

Figure 4.- Continued.



(d) B = 3.00 inches.

Figure 4.- Concluded.

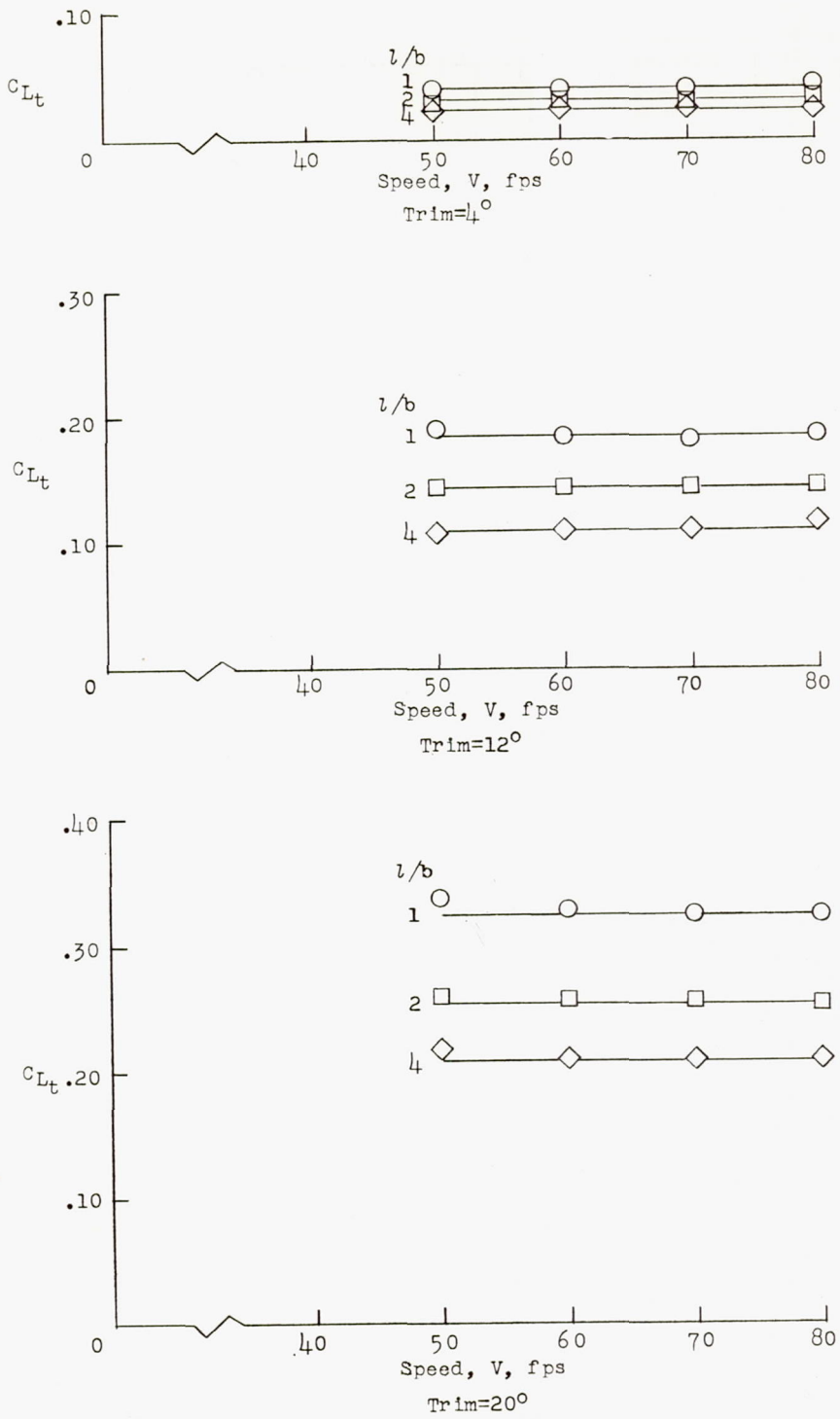


Figure 5.- Lift coefficients obtained in towing tank.

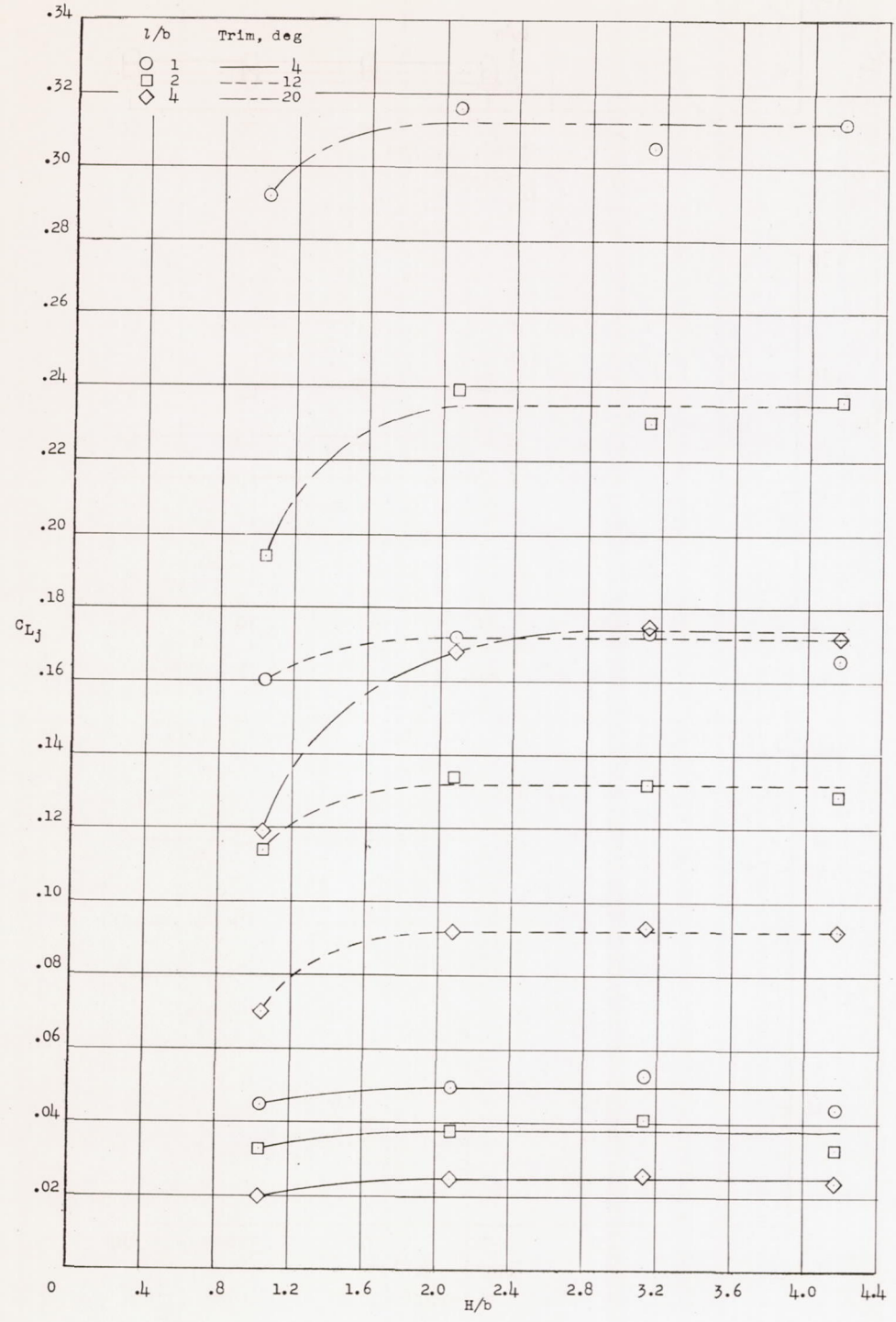


Figure 6.- Effect of jet depth on lift coefficients. Jet width, 2.08 model beams.

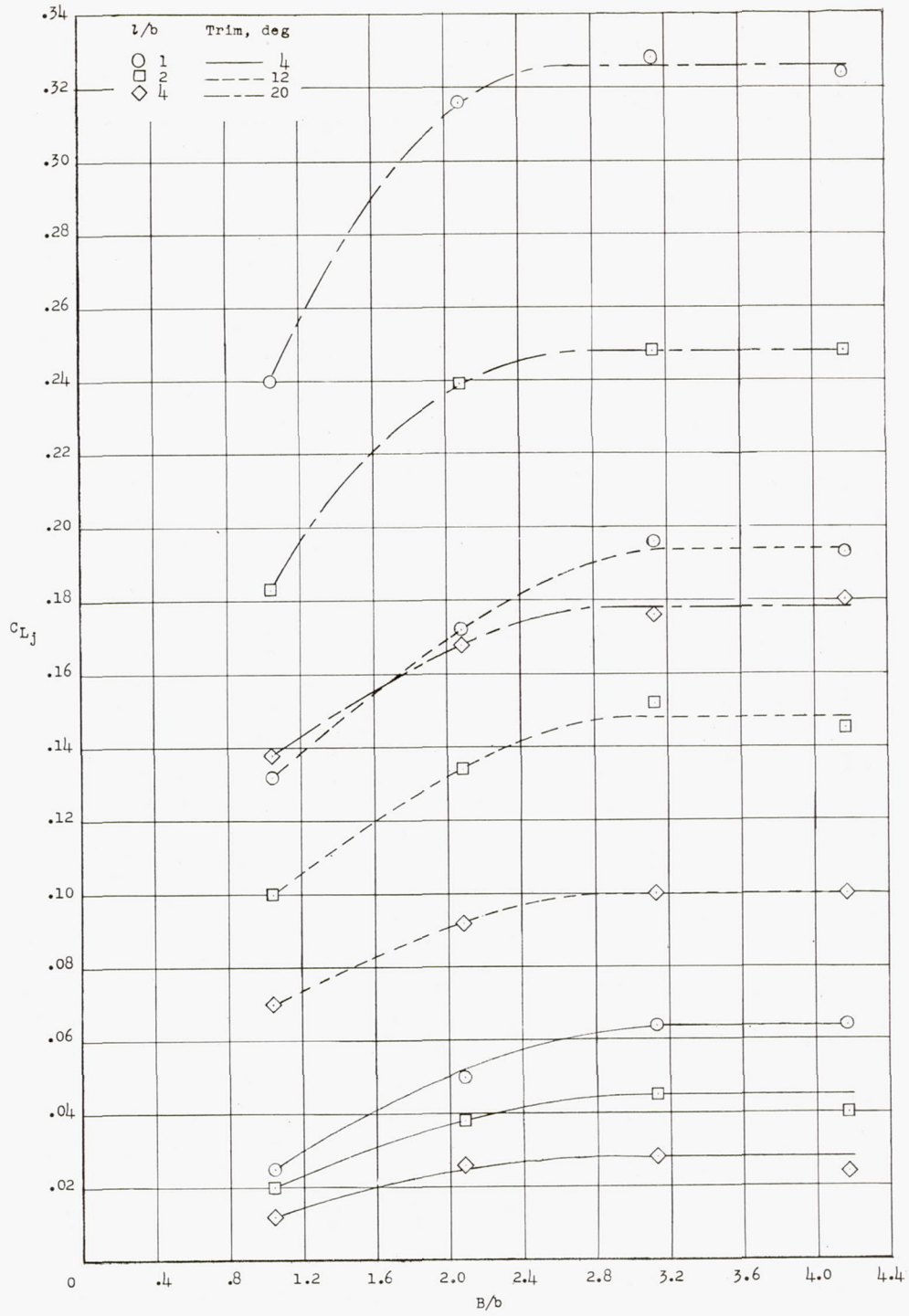


Figure 7.- Effect of jet width on lift coefficients. Jet depth, 2.08 model beams.

NACA - Langley Field, Va.

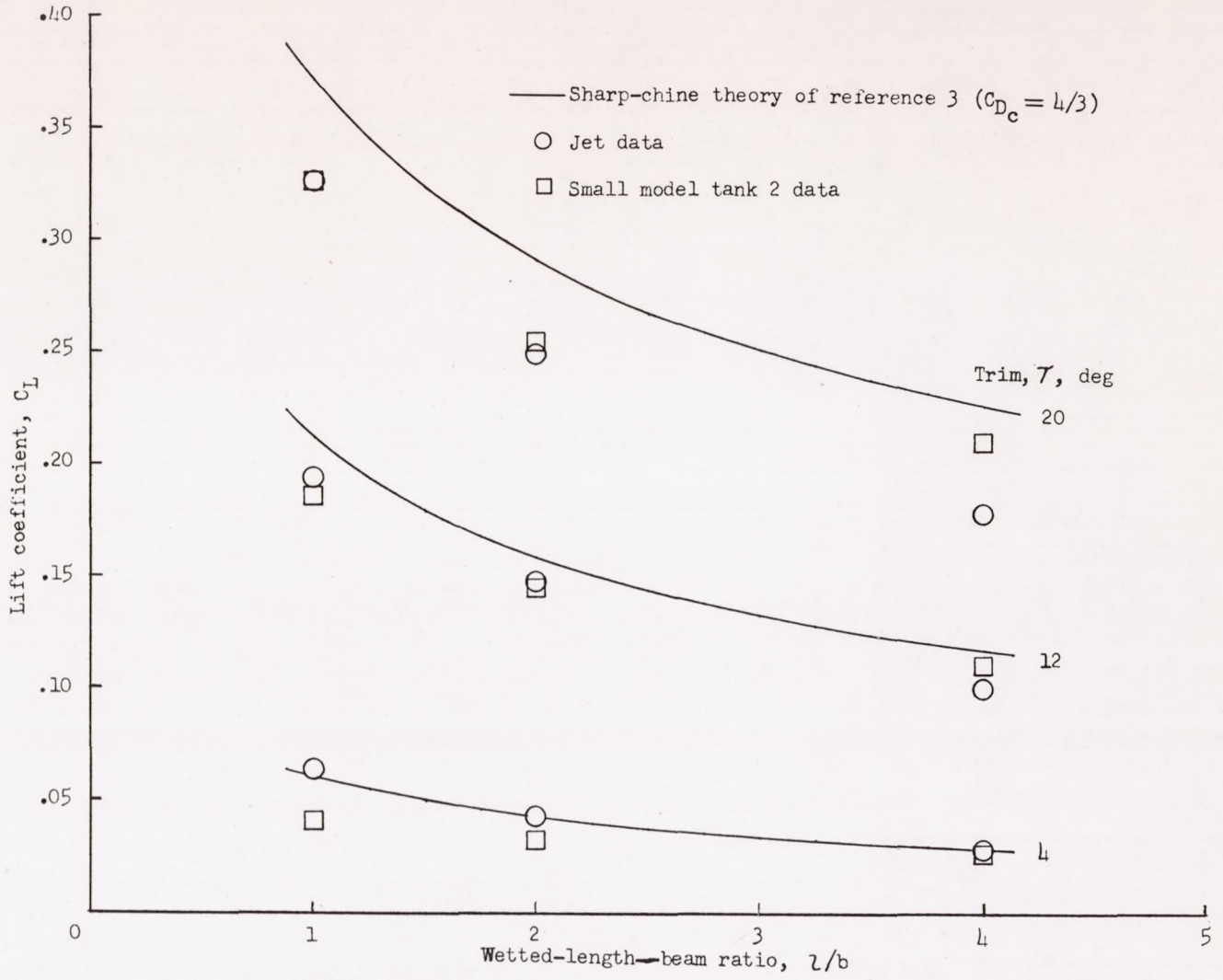


Figure 8.- Comparison of lift coefficients obtained from tests in jet (B = 3.0 inches; H = 1.5 inches), in tank, and those calculated from sharp-chine theory.